Operative Techniques in
Thoracic and
Cardiovascular Surgery

Transaortic Extended Septal Myectomy for Hypertrophic Cardiomyopathy

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Extended left ventricular septal myectomy is standard treatment for symptomatic patients with the obstructive variant of hypertrophic cardiomyopathy (HCM).[1] There is a definite learning curve to avoid the major technical complications, such as complete heart block, ventricular septal defect, or injury to the aortic or mitral valves or both. Our technique has evolved over the last 3 decades and differs from the classic Morrow myectomy. The standard indications for septal myectomy include symptoms refractory to medical treatment and severe left ventricular outflow tract (LVOT) obstruction with resting gradient of more than 30 mm Hg[2]; however, indications have expanded recently to include those symptomatic patients with low resting outflow gradients and latent obstruction.[3]

Operative Technique

After induction of general anesthesia and placement of routine monitoring lines needed for the cardiac surgical procedure, transesophageal echocardiography (TEE) is performed to confirm the cardiac anatomy and assess the mitral valve function and appearance of the ventricular septum. Additional information from TEE that may be helpful to the surgeon includes the maximum thickness of the interventricular septum, the distance of maximum thickness from the aortic annulus, the location of the endocardial fibrous plaque (friction lesion), and the apical extent of the septal bulge. A standard median sternotomy is preferred to provide adequate access to both the aorta and the left ventricle. We routinely measure simultaneous aortic and left ventricular pressures after aortic cannulation and before placement of the venous cannula. Success of surgery in obstructive HCM is dependent on elimination of any dynamic LVOT gradient. Provocative maneuvers may be necessary if no preoperative gradient can be elicited or if it is less than 30 mm Hg. These maneuvers include the measurement of the gradient after inducing a premature ventricular contraction by gently tapping on the heart (Brockenbrough-Braunwald-Morrow sign)[4] or by the administration of isoproterenol.

We favor normothermic cardiopulmonary bypass using a single, 2-staged venous cannula and cold blood cardioplegia with an initial dose of 1000-1200 ml to arrest and cool the hypertrophied ventricle. Adequate exposure of the subaortic septum is critically important, and several maneuvers facilitate the operation. Pericardial sutures are used only on the right side to elevate pericardium toward the surgeon and allow the left ventricle to fall posteriorly in the thorax. Next, an oblique aortotomy is made slightly closer to the sinotubular ridge than is usual for aortic valve replacement, and the incision is carried through the mid point of the noncoronary aortic sinus of Valsalva to a level approximately 1 cm above the valve annulus (Fig. 1). As illustrated in Figure 2, the edge of the proximal aorta is held out of the way with stay sutures of 4-0 polypropylene, and a cardiotomy sucker is placed through the aortic valve and used to depress the anterior leaflet of the mitral valve and protect it from injury (Fig. 3). The right aortic valve cusp is collapsed against the sinus wall where it will usually stay. A sponge stick is used to depress the right ventricle and rotate the septum posteriorly, orienting the left ventricle outflow anteriorly.

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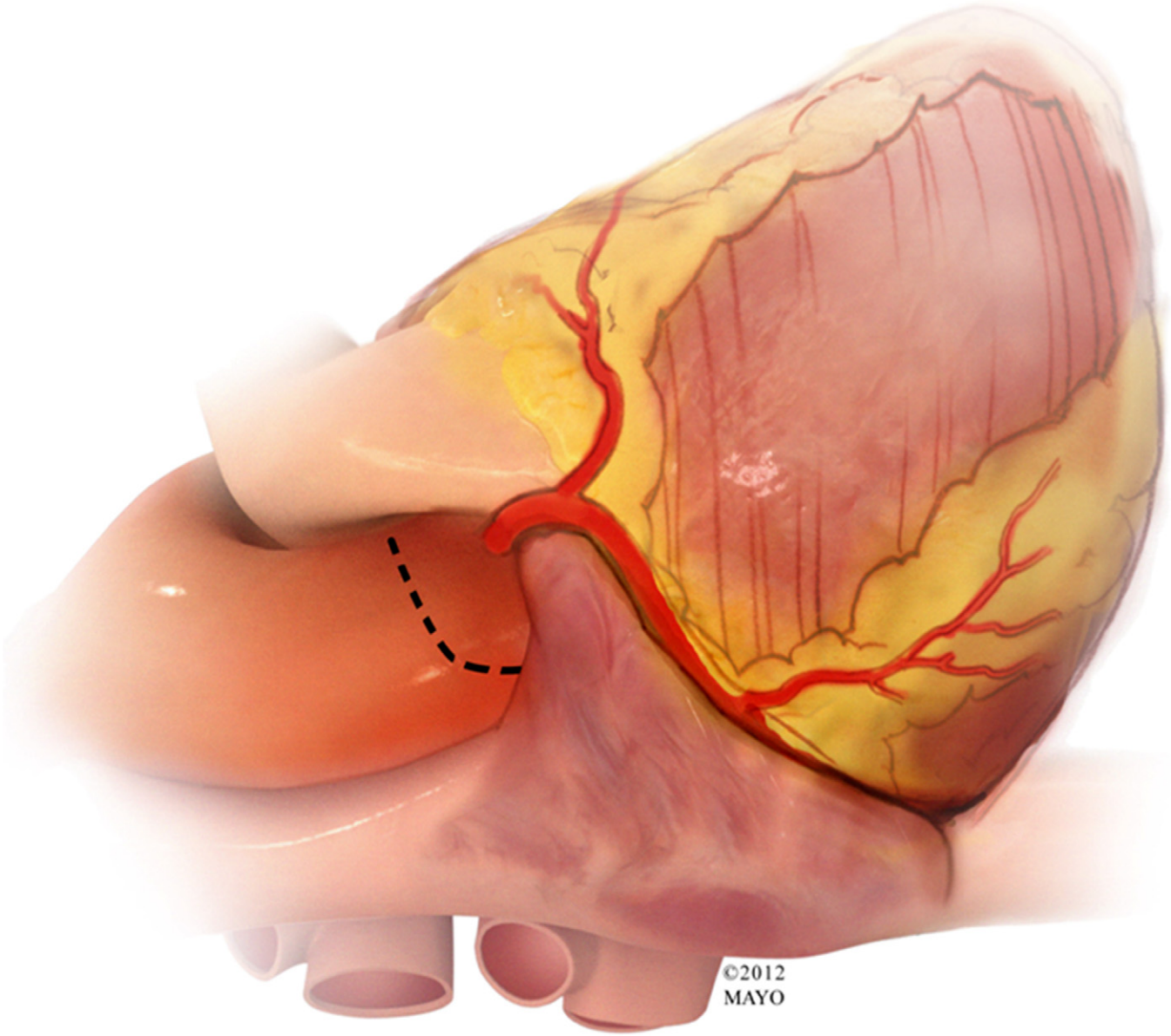

Figure 1 A hockey-stick aortotomy is made and extended inferiorly to the middle of the noncoronary sinus (dashed line). The aortotomy is carried to within 0.5-1.0 cm of the aortic annulus. This incision is made slightly closer to the sinotubular ridge than is usual for aortic valve replacement. (By permission of Mayo Foundation for Medical Education and Research. All rights reserved.) (Color version of figure is available online at http://www.optechtcs.com.)

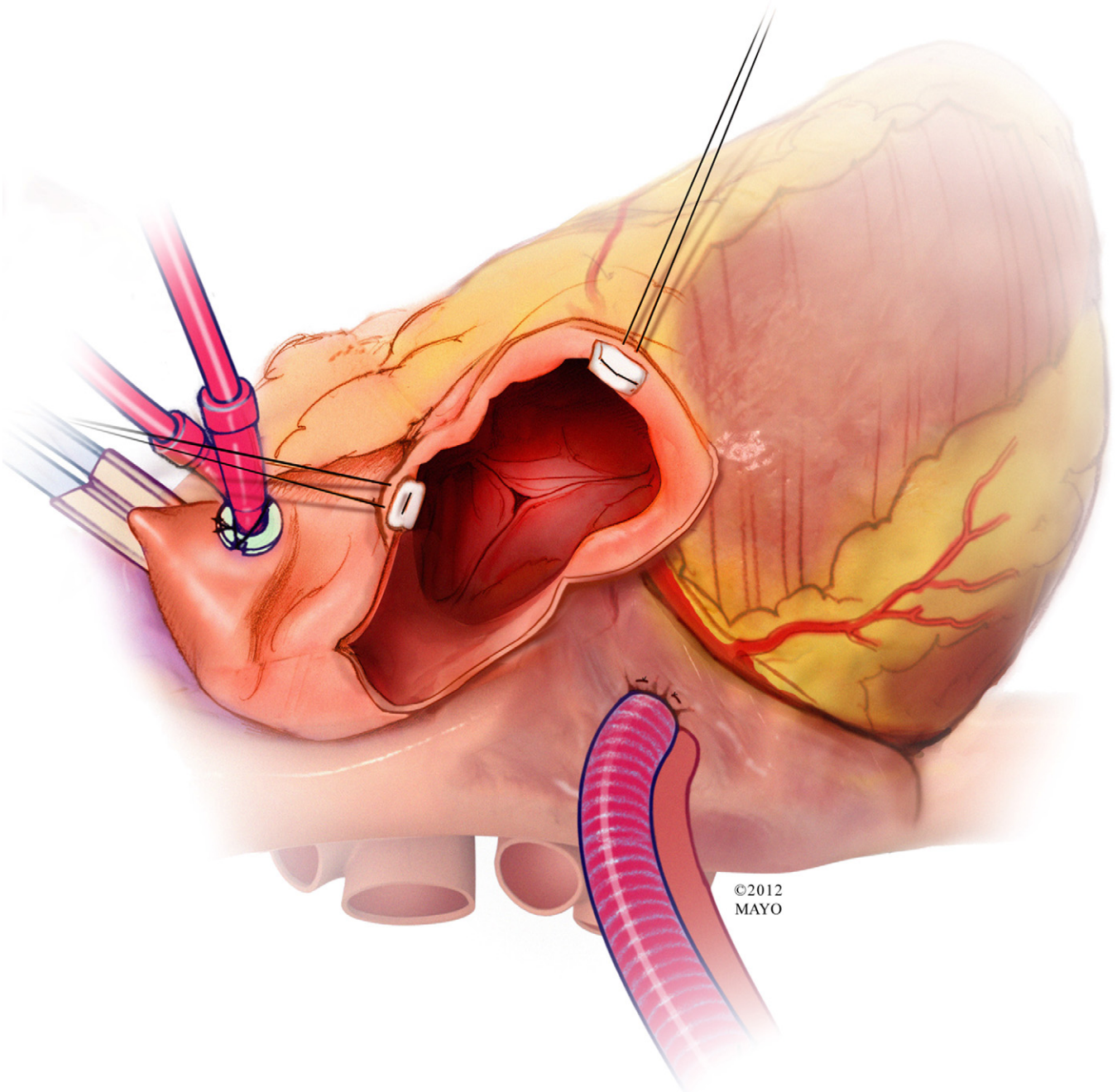

Figure 2 Suspension sutures of pledgeted 4-0 prolene are placed a few millimeters above the aortic valve commissures to maximize exposure of the hypertrophied septum and anterior mitral leaflet. (By permission of Mayo Foundation for Medical Education and Research. All rights reserved.) (Color version of figure is available online at http://www.optechtcs.com.)

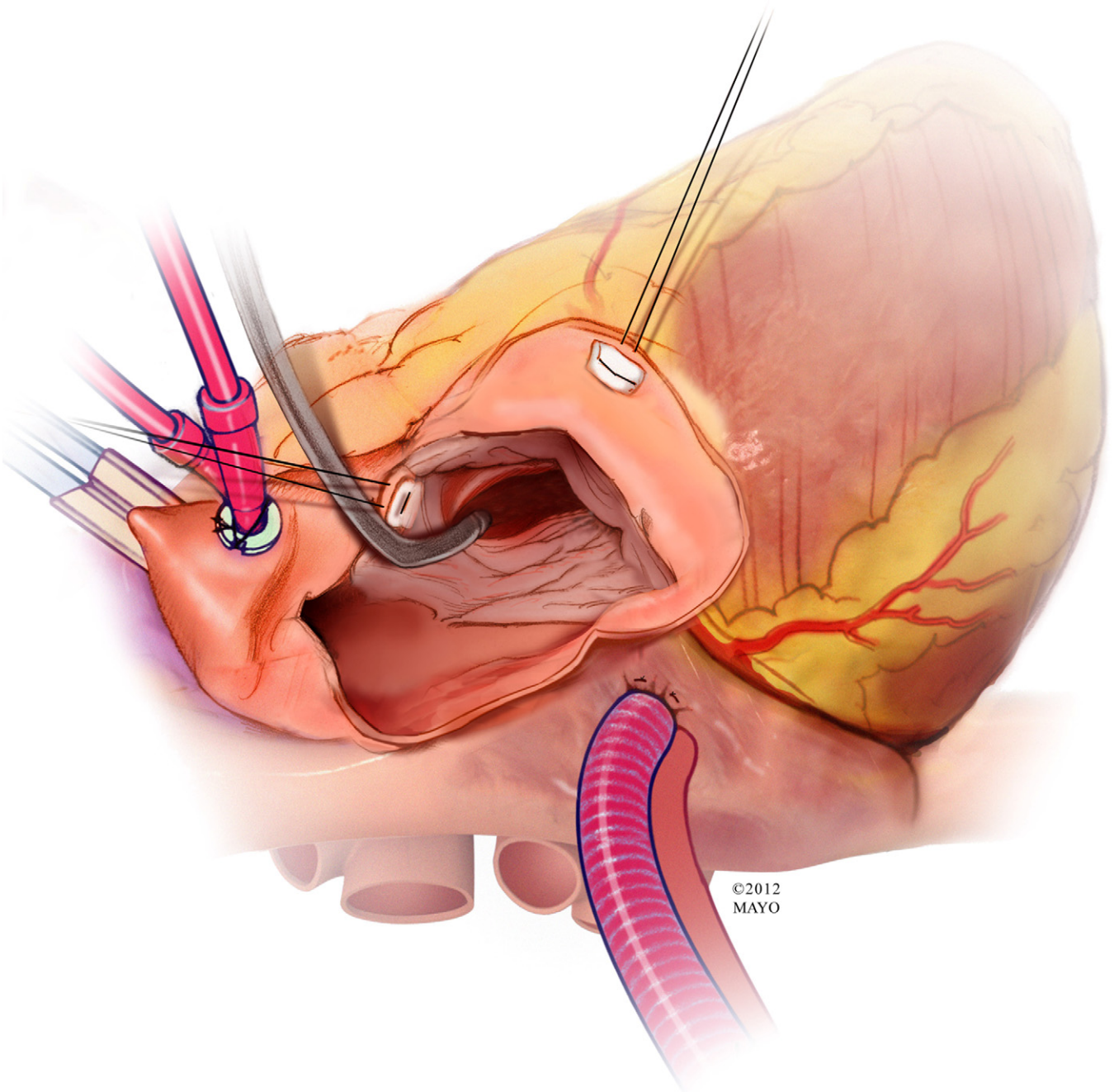

Figure 3 Several maneuvers facilitate the operation. Stay sutures are placed to retract the edges of the aortotomy. A small Yankauer suction is placed across the aortic annulus to retract the anterior mitral leaflet and papillary muscles posteriorly away from the ventricular septum. A closed forceps is used to retract the left coronary cusp. Inspection of the anatomy is performed, including identification of the friction (contact) lesion. (By permission of Mayo Foundation for Medical Education and Research. All rights reserved.) (Color version of figure is available online at http://www.optechtcs.com.)

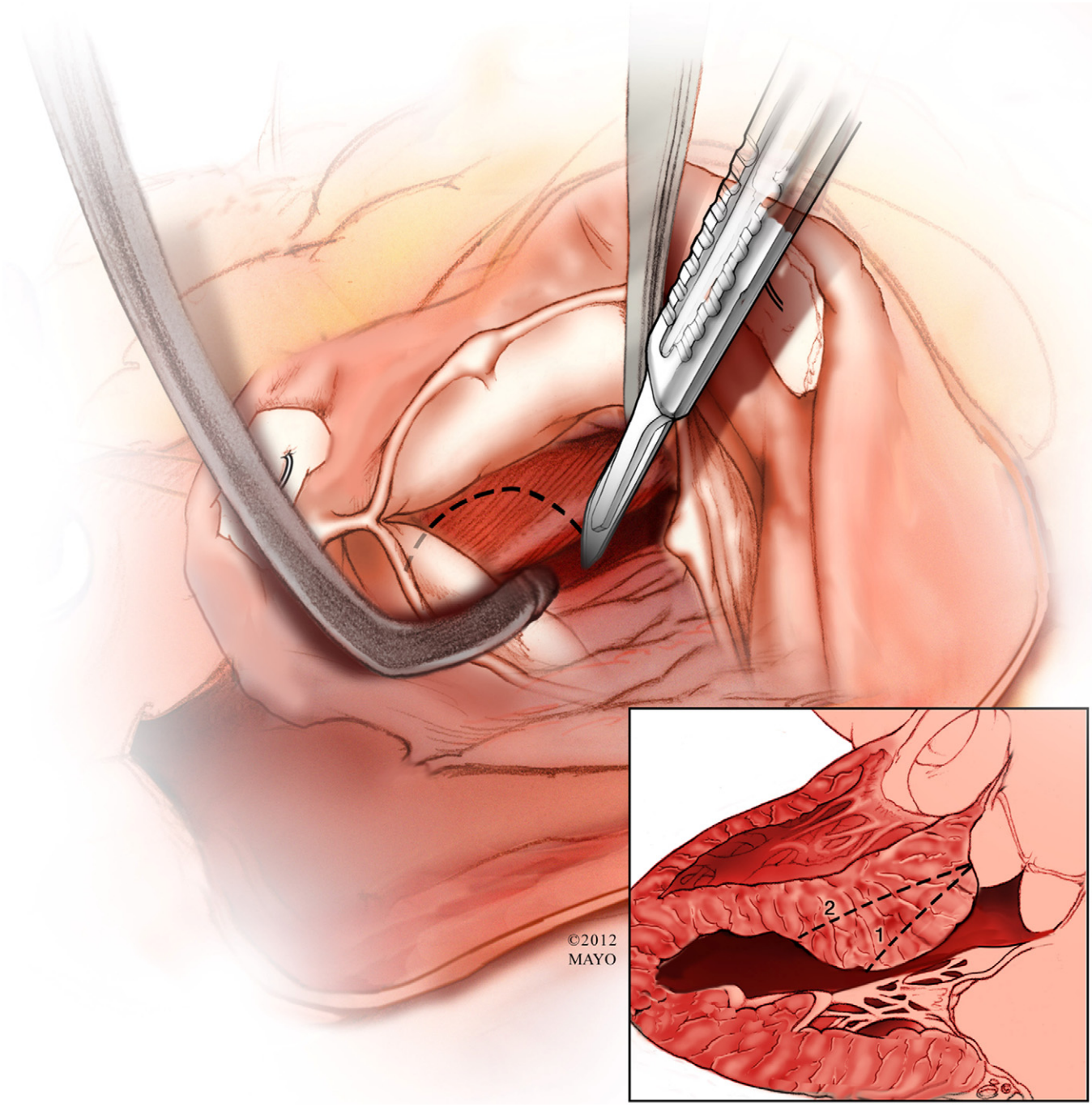

Figure 4 A standard Number 10 scalpel blade is used for incision in the septum that begins just to the right of the nadir of the right aortic sinus. Any incision made at the base of the ventricular septum more rightward than the nadir of the right cusp will injure the membranous septum and conduction tissue and result in complete heart block. It is also important to leave 8-10 mm of muscle immediately below the aortic annulus to prevent subsequent development of cusp prolapse and aortic regurgitation. (By permission of Mayo Foundation for Medical Education and Research. All rights reserved.) (Color version of figure is available online at http://www.optechtcs.com.)

A standard Number 10 scalpel blade is used for incision in the septum that begins just to the right of the nadir of the right aortic sinus (Fig. 4). The initial incision in the septum is made upward and then leftward over to the anterior leaflet of the mitral valve (Fig. 5). Scissors are used to complete the excision of this initial portion of myocardium. The area of septal excision is then deepened and lengthened toward the apex of the heart, being certain to excise hypertrophied septum beyond the endocardial scar (Fig. 6). Trabeculations and abnormal chordae are excised, and the myectomy site is further enlarged using pituitary rongeurs. Adequate septal myectomy usually yields 3-12 g of muscle. Depressing the heart

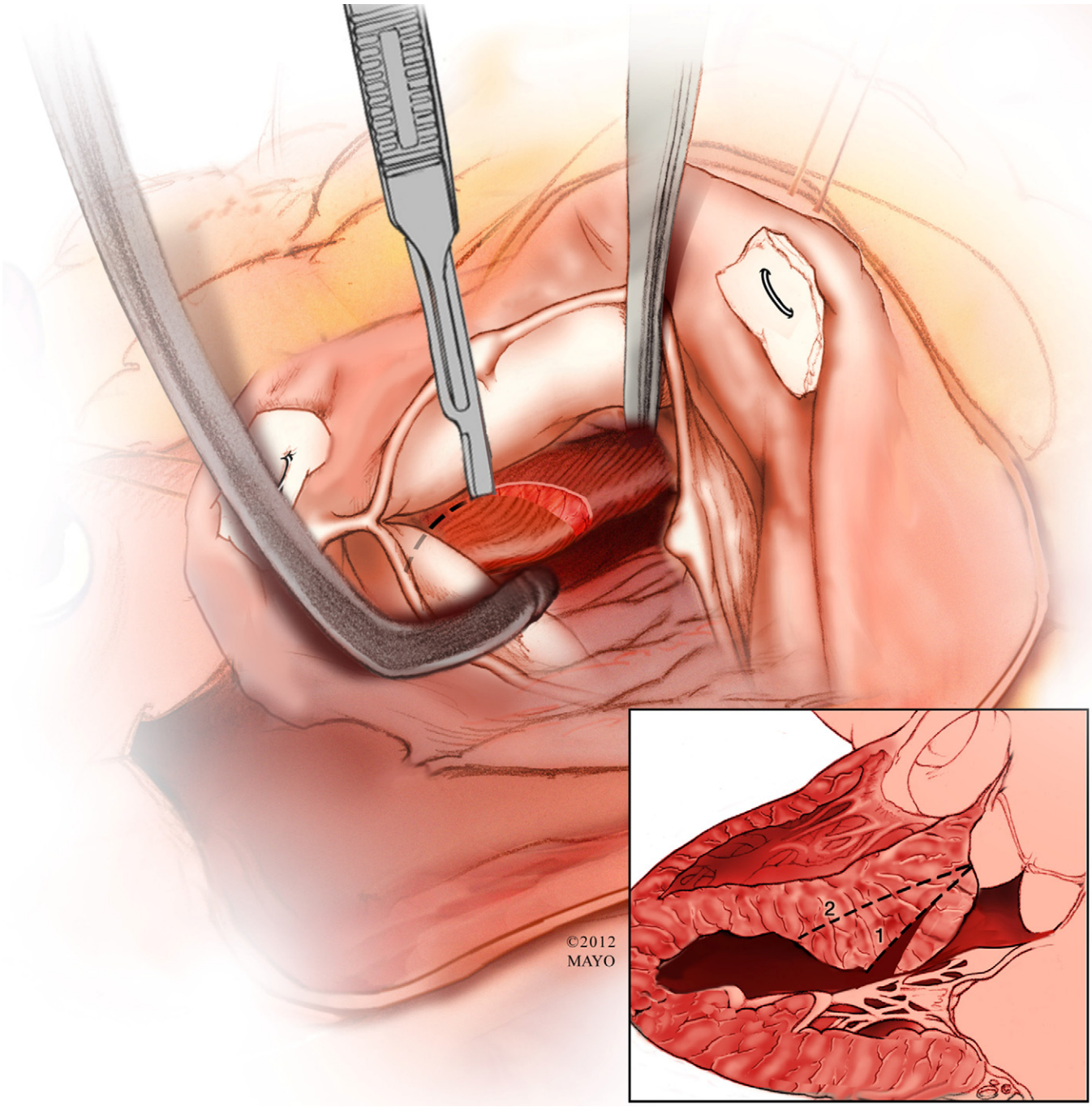

Figure 5 The initial incision in the septum (inset) is made upward and then leftward over to the anterior leaflet of the mitral valve. The area to the left of this incision is the left ventricular free wall. In general, the thickness of the resected muscle is two-thirds the thickness of septum (as measured by prebypass TEE images), while ensuring that the retained septum is at least 1 cm thick. (By permission of Mayo Foundation for Medical Education and Research. All rights reserved.) (Color version of figure is available online at http://www.optechtcs.com.)

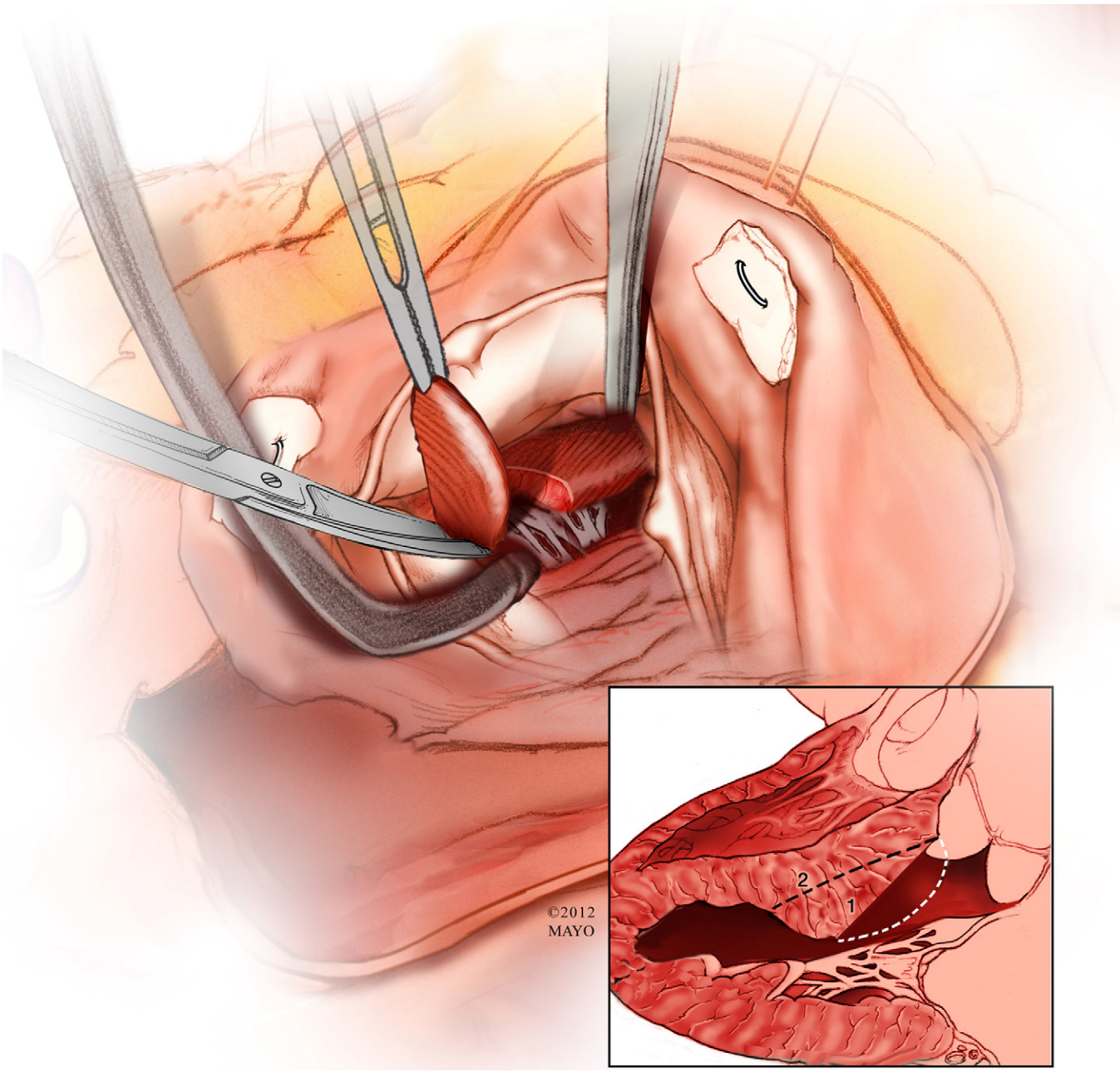

Figure 6 The area of septal excision is then deepened and lengthened toward the apex of the heart (second incision in the inset), being certain to excise hypertrophied septum beyond the endocardial scar. Trabeculations are excised, and the myectomy site is further enlarged using pituitary rongeurs. (By permission of Mayo Foundation for Medical Education and Research. All rights reserved.) (Color version of figure is available online at http://www.optechtcs.com.)

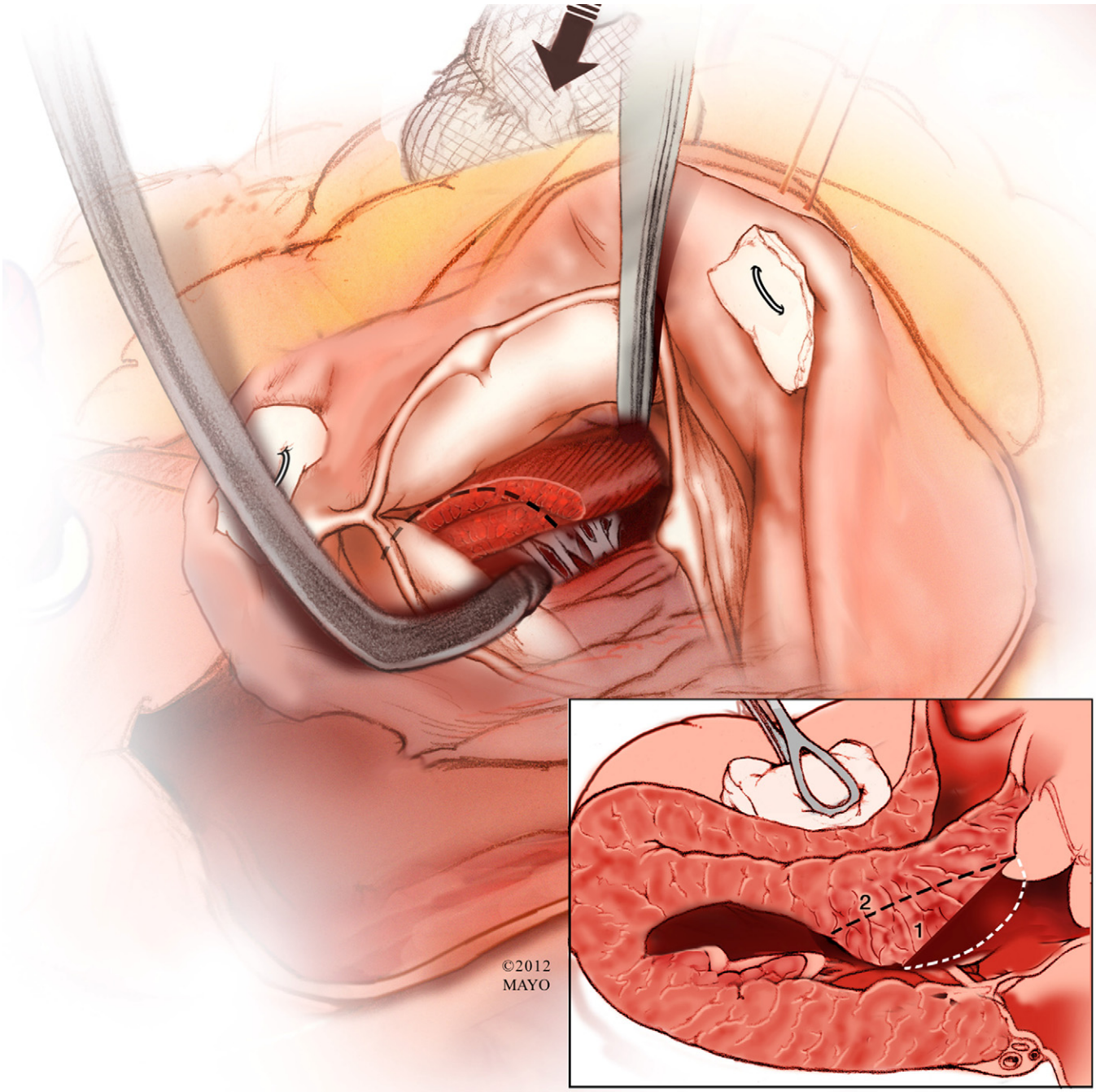

Figure 7 Optimal visualization of the ventricular septum is facilitated by the posterior displacement of the anterior wall of the left ventricle with a sponge forceps (arrow). Frequent repositioning of the sponge forceps and suction cannula is critical for maintaining exposure of the desired areas of resection. The suction cannula is again used to retract the mitral valve chordae and papillary muscles out of the way so that exposure of the lower septum is optimized. (By permission of Mayo Foundation for Medical Education and Research. All rights reserved.) (Color version of figure is available online at http://www.optechtcs.com.)

posteriorly with a sponge stick will improve exposure of the distal extent of the myectomy (Fig. 7). Direct inspection and digital palpation evaluate the adequacy and distal extent of the resection (Fig. 8). The most common reasons for residual gradients are inadequate septectomy at midventricular level and overlooked anomalous papillary muscles. In general, one can visualize the papillary muscles and chordae while looking through the aortic root after the myectomy has been completed (Figs. 9-11). The aortic and mitral valves are inspected to insure that there has been no injury to them. The aortotomy is closed in 2 layers with 4-0 polypropylene suture, and then the operation proceeds as usual.

This technique for more extended myectomy differs from the standard Morrow operation in which parallel incisions create a trough in the septum that extends up to 3 cm from the aortic valve. With the extended myectomy, the wider excision of muscle in the immediate subaortic area improves exposure of the distal extent of the hypertrophied septum, and excision extends up to 7 cm from the aortic valve. Inadequate myectomy results more often from failure to excise a sufficient length of the sep-

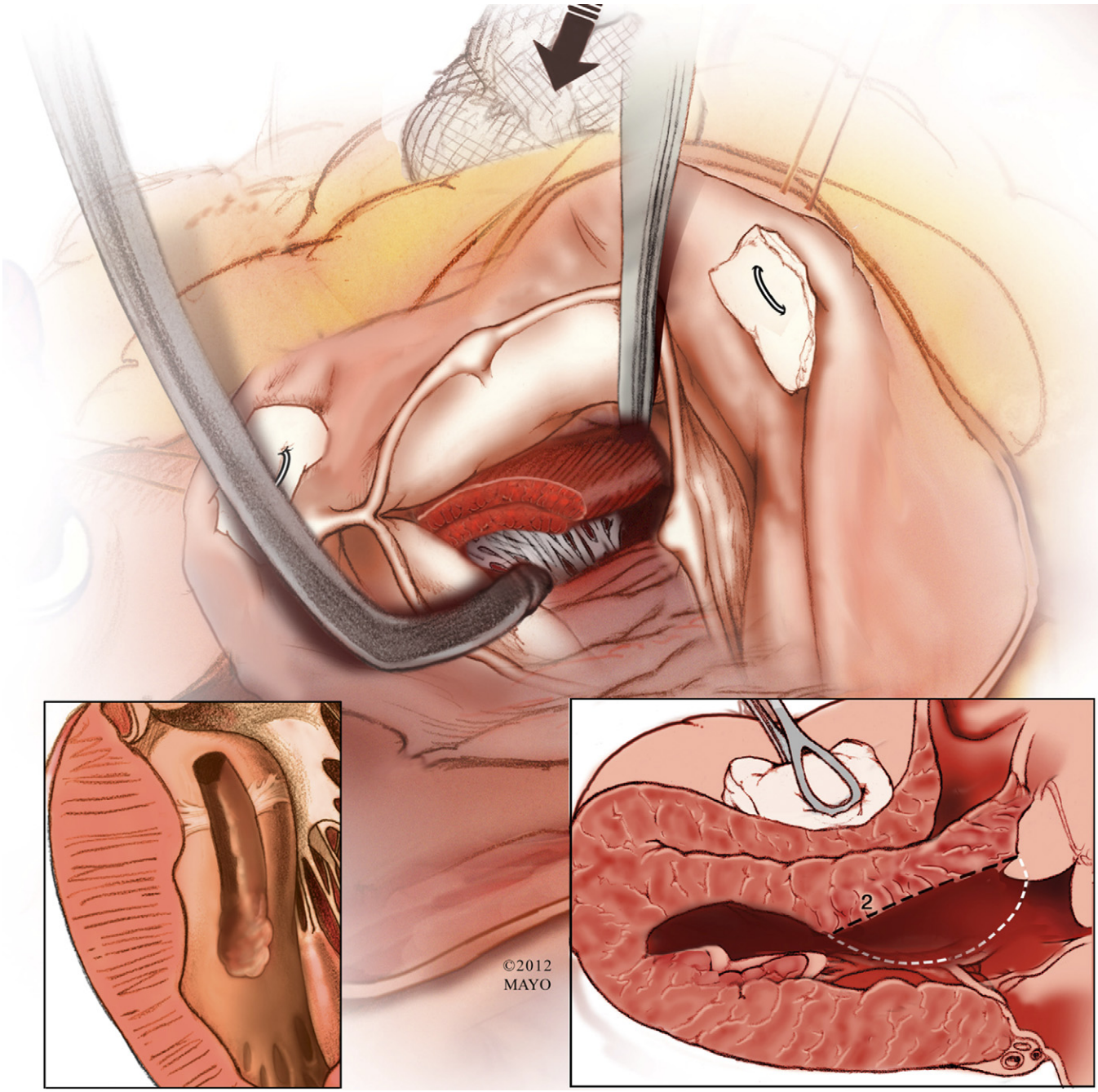

Figure 8 The completed left ventricular septal myectomy usually yields 3-12 g of muscle and extends from the subaortic level to the midventricular level, opposite to the base of the anterior papillary muscle of the mitral valve to eliminate any left ventricular outflow gradient. (By permission of Mayo Foundation for Medical Education and Research. All rights reserved.) (Color version of figure is available online at http://www.optechtcs.com.)

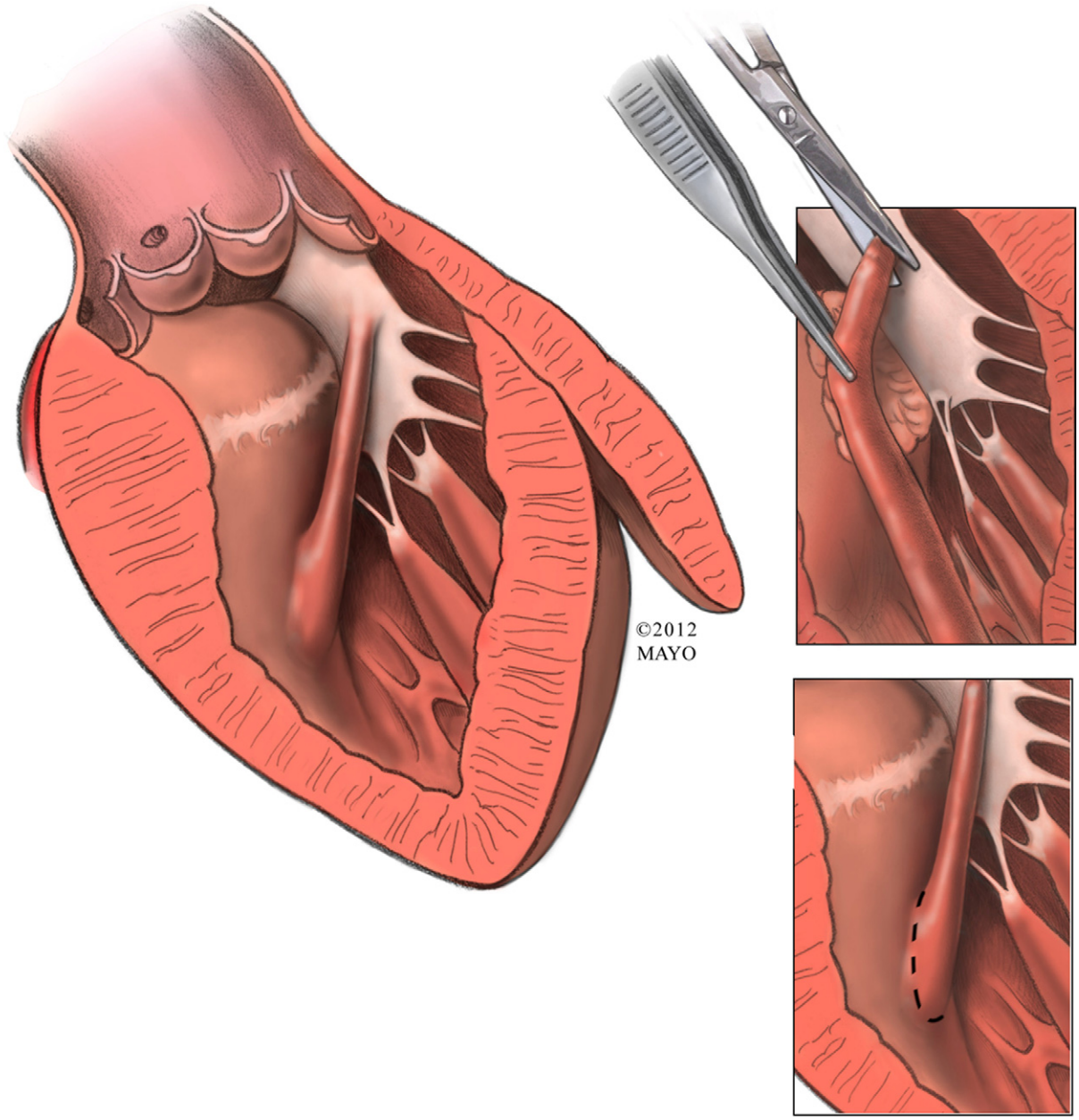

Figure 9 After the classical and extended portions of the resection are completed, inspection of the subvalvar apparatus for any mitral valve abnormalities should be performed. This figure demonstrates an example of an accessory papillary muscle that arises from the ventricular septum. The fibrous attachments to the side of the anterior mitral leaflet can be seen. Anomalous papillary muscles may contribute to LVOT obstruction and can be safely excised (dotted line) if the point of insertion is not on the free margin of the leaflet. (By permission of Mayo Foundation for Medical Education and Research. All rights reserved.) (Color version of figure is available online at http://www.optechtcs.com.)

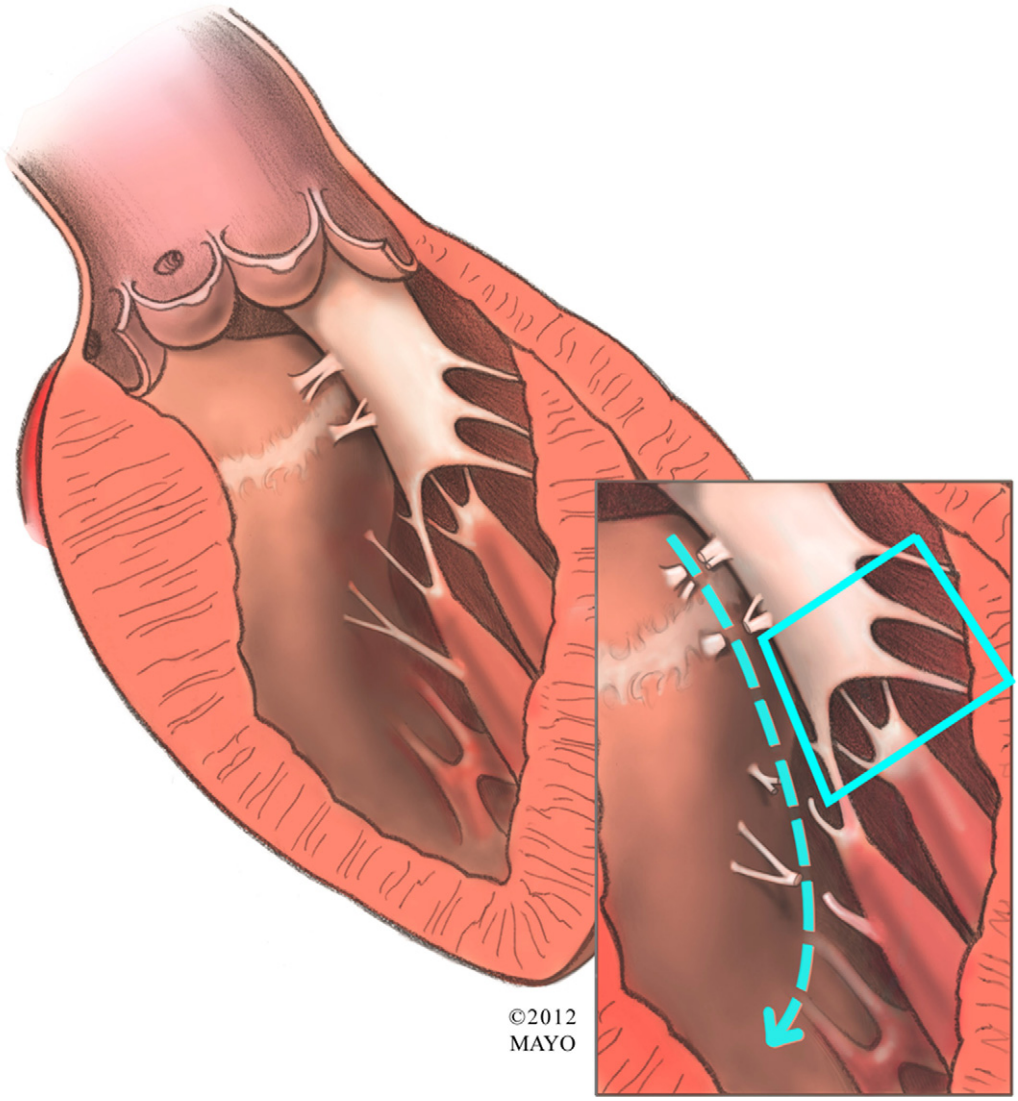

Figure 10 This figure demonstrates examples of abnormal chordal and subvalvar attachments that may be present in hypertrophic cardiomyopathy. There may be fibrous attachments between the side of the anterior mitral leaflet and the ventricular septum or free wall, and there may be additional (accessory) papillary muscles or chordae that join the anterolateral papillary muscle to the ventricular septum. These abnormalities are also addressed at the time of myectomy because they can contribute to LVOT obstruction, limiting mobility of the anterior leaflet and/or papillary muscle and subvalvar apparatus to move out of the LVOT during systole. It is important to maintain all chordal attachments to the leading edge of the anterior mitral leaflet. This is shown in the box incorporating the leading edge of the anterior mitral leaflet. (By permission of Mayo Foundation for Medical Education and Research. All rights reserved.) (Color version of figure is available online at http://www.optechtcs.com.)

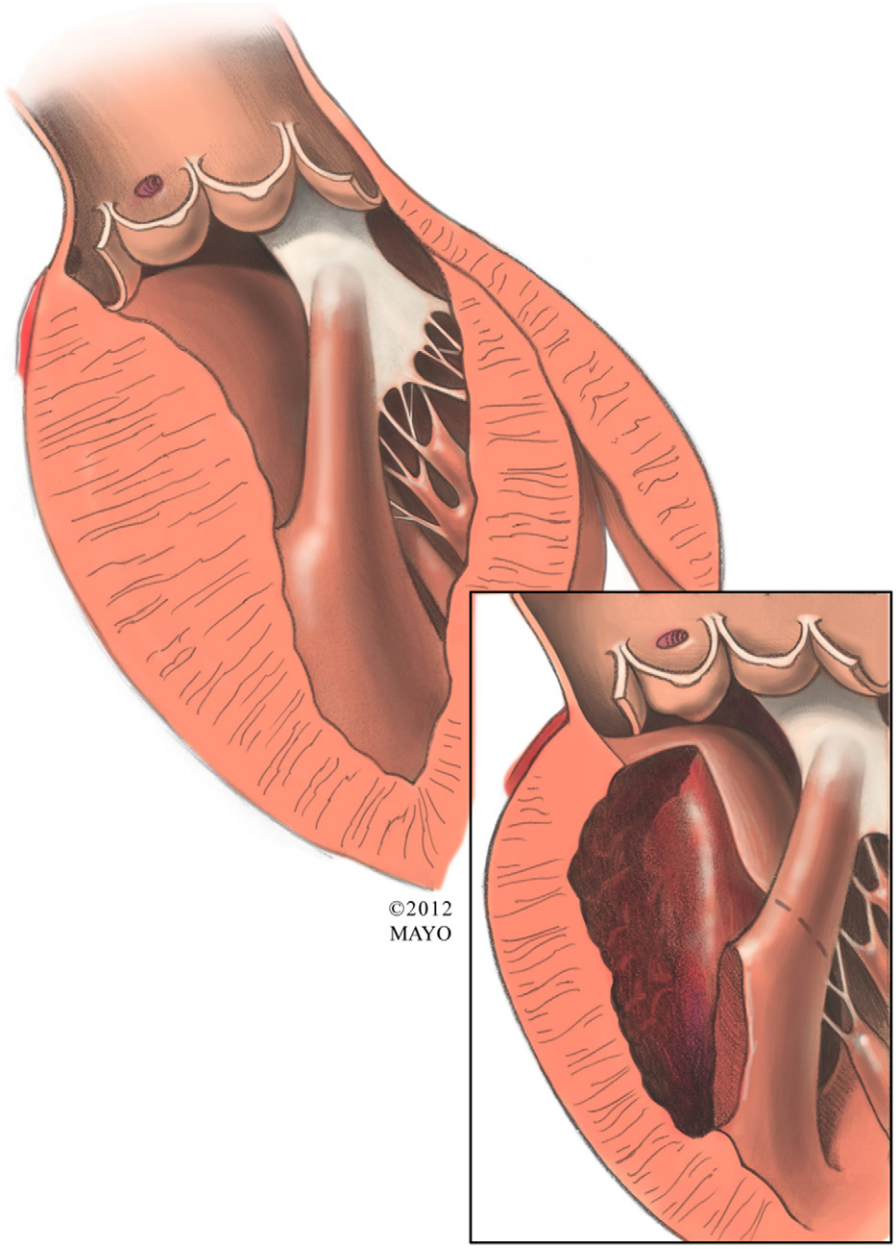

Figure 11 Direct insertion of the head of the often large anterolateral papillary muscle into the anterior leaflet of the mitral valve may contribute to outflow obstruction. The muscle insertion site is frequently adjacent to the commissure of the mitral valve. In addition to direct insertion of the papillary muscle into the anterior leaflet, there is often concomitant fusion of the papillary muscle to the left ventricular septum or free wall. Following extended septal myectomy as previously described, the papillary muscle is incised from the left ventricular septum or free wall down to its base (inset). (By permission of Mayo Foundation for Medical Education and Research. All rights reserved.) (Color version of figure is available online at http://www.optechtcs.com.)

tum (toward the apex) than from inadequate depth of excision. Importantly, the methods described above have proven adequate for all patients with subaortic obstruction, and maneuvers, such as anterior leaflet plication are unnecessary and, we believe, potentially harmful. Mitral valve replacement is reserved for patients with intrinsic leaflet abnormalities that cannot be repaired. To confirm complete relief of the LVOT obstruction, we repeat measurement of simultaneous aortic and left ventricular pressure by direct needle puncture after myectomy after the patient is weaned from cardiopulmonary bypass. In most patients there will be no residual gradients after myectomy and near complete elimination of systolic anterior motion (SAM). Provoked gradients of more than 15 mm Hg would prompt resumption of cardiopulmonary bypass and further excision of septal muscle. TEE is repeated to confirm relief of LVOT obstruction, identify obstruction at any other level, and confirm that there is no ventricular septal defect or injury to the aortic valve.

Mayo Clinic Experience

More than 2000 patients have had septal myectomy for HCM at the Mayo Clinic. In experienced centers, risk of hospital death after isolated septal myectomy for obstructive HCM is $<1\%$ and is similar to the risk of operation for elective mitral valve repair. Complications, such as complete heart block

requiring permanent pacemaker and iatrogenic ventricular septal perforation, have become uncommon, although partial or complete left bundle branch block is a frequent finding on the postoperative electrocardiogram. Usually, this is not associated with adverse sequelae, but if the patient has complete right bundle branch block preoperatively, injury to the left bundle after myectomy increases the risk of complete heart block. This is particularly important in patients who have had alcohol septal ablation before operation, which leads to right bundle branch block in up to 60% of patients.[5]

Relief of LVOT obstruction with septal myectomy dramatically improves symptoms in exercise capacity in symptomatic patients with obstructive HCM. In our experience, approximately 90% of severely symptomatic patients have improvement of ≥2 function classes, and relief of outflow gradients by myectomy is equally effective in improving limitations because of dyspnea, angina, or syncope.[6] Importantly, symptomatic benefit of myectomy is related directly to reducing the basal outflow gradient and mitral regurgitation (MR) and improving left ventricular systolic and end-diastolic pressures (in more than 90% of patients), which, in turn, may also favorably influence left ventricular diastolic filling and myocardial ischemia. Relief of the gradient may decrease left atrial size and the subsequent risk of developing atrial fibrillation.

Late recurrence of significant resting left ventricular outflow gradients is very uncommon after successful myectomy in either adults or children with obstructive HCM, and this is in contrast to patients who have surgery for relief of congenital membranous subaortic stenosis.[7,8] Common causes of recurrent LVOT obstruction and symptoms include limited myectomy at the first operation, mid ventricular obstruction, and anomalies of papillary muscles.[9] Most often, inadequate myectomy at the initial operation is due to failure to extend the myectomy far enough toward the apex of the heart.

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